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Utilization of Lightweight Materials Made From Coal Gasification Slags

Quarterly Report
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For
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1.0 PROJECT OBJECTIVES, SCOPE AND DESCRIPTION OF TASKS

1.1 Introduction

Integrated-gasification combined-cycle (IGCC) technology is an emerging technology that utilizes coal for power generation and production of chemical feedstocks. However, the process generates large amounts of solid waste, consisting of vitrified ash (slag) and some unconverted carbon. In previous projects, Praxis investigated the utilization of "as-generated" slags for a wide variety of applications in road construction, cement and concrete production, agricultural applications, and as a landfill material. From these studies, we found that it would be extremely difficult for "as-generated" slag to find large-scale acceptance in the marketplace even at no cost because the materials it could replace were abundantly available at very low cost. It was further determined that the unconverted carbon, or char, in the slag is detrimental to its utilization as sand or fine aggregate. It became apparent that a more promising approach would be to develop a variety of value-added products from slag that meet specific industry requirements. This approach was made feasible by the discovery that slag undergoes expansion and forms a lightweight material when subjected to controlled heating in a kiln at temperatures between 1400 and 1700°F. These results confirmed the potential for using expanded slag as a substitute for conventional lightweight aggregates (LWA). The technology to produce lightweight and ultra-lightweight aggregates (ULWA) from slag was subsequently developed by Praxis with funding from the Electric Power Research Institute (EPRI), Illinois Clean Coal Institute (ICCI), and internal resources.

The major objectives of the subject project are to demonstrate the technical and economic viability of commercial production of LWA and ULWA from slag and to test the suitability of these aggregates for various applications. The project goals are to be accomplished in two phases: Phase I, comprising the production of LWA and ULWA from slag at the large pilot scale, and Phase II, which involves commercial evaluation of these aggregates in a number of applications.

Primary funding for the project is provided by DOE's Morgantown Energy Technology center (METC) with significant cost sharing by Electric Power Research Institute (EPRI) and Illinois Clean Coal Institute (ICCI).

1.2 Scope of Work

The Phase I scope consisted of collecting a 20-ton sample of slag (primary slag), processing it for char removal, and pyroprocessing it to produce expanded slag aggregates of various size gradations and unit weights, ranging from 12 to 50 lb/ft^3. In Phase II, the expanded slag aggregates will be tested for their suitability in manufacturing precast concrete products (e.g., masonry blocks and roof tiles) and insulating concrete, first at the laboratory scale and subsequently in commercial manufacturing plants. These products will be evaluated using ASTM and industry test methods. Technical data generated during production and testing of the products will be used to assess the overall technical viability of expanded slag production. Relevant cost data for physical and pyroprocessing of slag to produce expanded slag aggregates will be gathered for comparison with (i) the management and disposal costs for slag or similar wastes and (ii) production costs for conventional materials which the slag aggregates would replace. In addition, a market assessment will be made to evaluate the economic viability of these utilization technologies.

1.3 Phase I Task Description

A summary of the tasks performed in Phase I is given below:

Task 1.1 **Laboratory and Economic Analysis Plan Development**: Development of a detailed work plan for Phase I and an outline of the Phase II work.

Task 1.2 **Production of Lightweight Aggregates from Slag**: This task covered selection and procurement of project slag samples, slag preparation including screening and char removal, and slag expansion in a direct-fired kiln and fluid bed expander. The char recovered from the slag preparation operation was evaluated for use as a kiln fuel and gasifier feed. Environmental data for slag-based lightweight aggregate (SLA) production was collected.

Task 1.3 **Data Analysis of Slag Preparation and Expansion**: Analysis and interpretation of project data, including development of material and energy balances for slag processing and product evaluation.

Task 1.4 **Economic Analysis of Expanded Slag Production**: Economic analysis of the utilization of expanded slag was conducted by determining production costs for slag-based LWAs and ULWAs. Expanded slag production costs were compared with the market value of similar products both with and without taking into account the avoided costs of disposal and with the costs of management of slag as a solid waste.

Task 1.5 **Topical and Other Reports**: Preparation topical, financial status, and technical progress reports in accordance with the Statement of Work.

1.4 Phase II Task Description

A summary of the tasks to be performed in Phase II is given below.

Task 2.1 **Test Plan for Applications of Expanded Slags (Field Studies)**: This task involves the development of selection criteria and a field test plan for applications of expanded slag. This plan will serve as a guide in the selection and implementation of field demonstrations for the most promising expanded slag utilization applications. Field applications will be selected on the basis of laboratory results, the marketability of the products, and the suitability of the project slags for producing them. The following applications are under consideration for testing:

- Lightweight concrete blocks made from 50 lb/ft^3 SLA
- Lightweight roof tiles made from 40 lb/ft^3 SLA
- Loose fill insulation made from 16 lb/ft^3 SLA
- Lightweight insulating concrete made from 16 lb/ft^3 SLA

Task 2.2 **Field Studies to Test Expanded Slag Utilization**: Under this task, field testing of the applications identified in Phase II, Task 2.1, will begin with test work to optimize the concrete mixes made from expanded slag.

Task 2.3 **Data Analysis of Commercial Utilization of Expanded Slags:** The objective of this task is to assimilate the data and test results collected during Phase II, Task 2.2, to convert these findings to common engineering terms, and to correlate these results with comparable information for conventional lightweight aggregates as reported in the literature. The data analysis will provide specific answers to the following issues:

- Performance of expanded slag compared with that of conventional materials
- Technical viability of lightweight and ultra-lightweight slags as aggregates.

Task 2.4 **Economic Analysis of Expanded Slag Utilization:** The objective of this task is to expand upon the preliminary economic assessment of expanded slag utilization conducted during Phase I. The economics will be studied based on the production costs for SLA in comparison with current market prices for conventional materials. During the Phase I preliminary evaluation, two production scenarios emerged:

- Production of SLA at the gasifier location (on-site production)
- Production of SLA at a lightweight aggregate facility (off-site production)

The impact of the avoided costs of slag disposal on the economics of SLA production will also be evaluated. Slag utilization data and product samples will be made available to commercial lightweight aggregate users for validation of estimated market prices. The impact of SLA market prices on the economics of SLA production will also be studied.

Task 2.5 **Final Report:** The data generated and collected during the project will be compiled in a final report to be submitted at the end of the project that will be a comprehensive description of the results achieved, consistent with the Reporting Requirements. Data from topical and field reports will be summarized. The report will include the original hypothesis of the project and present the investigative approaches used, complete with problems encountered or departures from the planned methodology, and an assessment of their impact on the project results.

1.5 Scope of This Document

This is the tenth quarterly report and summarizes the work undertaken during the performance period between 1 December 1996 and 28 February 1997. This is the third quarterly report for Phase II. This document summarizes the Phase II accomplishments to date along with the major accomplishments from Phase I.

2.0 SUMMARY OF WORK DONE DURING THIS REPORTING PERIOD

2.1 Summary of Major Accomplishments

The following was accomplished during the current reporting period:

1. Laboratory testing of mix designs for the production of lightweight and regular concrete blocks was conducted. The data indicate that SLA may be used as a substitute for commercial LWA.

2. Testing of expanded slag for the structural concrete application was completed. The results indicate that structural concrete can be made to meet the ASTM compressive strength requirement of 2500-4000 psi at the corresponding unit weight of 105-115 lb/ft^3 using 50/50 SLA (i.e., pelletized expanded product made from 50/50 slag/clay).

3. Expanded slag is undergoing testing and evaluation for horticultural/nursery applications by a major nursery in Tennessee.

2.2 Chronological Listing of Significant Events in This Quarter

The following significant events occurred during the current reporting period:

Date	Description
1/10/97	Laboratory testing of SLA for structural concrete application completed
2/19/97	First batch of laboratory tests of selected block mixes completed

3.0 TO DATE ACCOMPLISHMENTS

A summary of the work completed in Phase I is given below.

Date	Phase I Accomplishments
10/24/94	Draft Laboratory and Economic Analysis Plan (project work plan) submitted
11/18/94	Slag char removal completed on the advance sample and prepared slag laboratory expansion testing initiated
12/02/94	Final "Laboratory and Economic Analysis Plan" prepared and submitted
05/21/95	Primary slag sample (20 ton) received at Penn State for preparation
06/01/95	Pilot unit for char removal set up and processing work started
08/20/95	Primary slag sample processing for char removal completed
9/10/95	Laboratory expansion studies of slag and slag/clay blends started
10/15/95	1-ft and 3-ft diameter kilns commissioned for pilot testing
11/15/95	Pilot testing of Slag I and Slag II and pellets in 3-ft dia. direct-fired kiln completed
11/17/95	Pilot testing using fluidized bed expander completed
12/12/95	SLA product characterization initiated
1/20/96	Laboratories for testing of SLA products identified
2/16/96	Test plan for second batch of fluid bed expander testing at Fuller completed
4/30/96	Application for continuation of the project to Phase II submitted
5/31/96	Phase I Final Report (draft) submitted to METC

A summary of the work completed in Phase II to date is given below.

Date	Description
7/1/96	Phase I Topical Report (final version) submitted
7/14/96	Approval for continuation of the project to Phase II was received from METC
7/14/96	Structural concrete laboratory tests started
7/15/96	Laboratory testing of SLA for roof tile and insulating concrete applications completed
7/15/96	Evaluation of SLA for completed
7/30/96	Evaluation of SLA for loose fill insulation completed
10/10/96	Mix designs for block production selected
11/10/96	Laboratory evaluation of the Slag II completed
10/30/96	Structural concrete laboratory tests completed
11/10/96	Laboratory evaluation of Slag III for LWA production completed
1/10/97	Laboratory testing of SLA for structural concrete application completed
2/19/97	First batch of laboratory tests of selected block mixes completed

4.0 TECHNICAL PROGRESS REPORT

4.1 Manufacturing and Testing of Masonry Blocks

The objective of this subtask is to use commercial-scale concrete block manufacturing equipment and techniques to produce blocks from expanded slag. This work is being done at the facilities of Harvey Cement Products, Inc., a major block manufacturer and distributor in the greater Chicago area. Harvey Cement was selected as they are located close to the recently commissioned Wabash River IGCC plant which is a potential long-term source of slag and hence slag-based LWA. A number of block mix designs were developed by Praxis based on particle size distribution and unit weight information obtained from Harvey Cement.

ASTM C 331 specifies unit weight values for aggregates and unit weight and strength requirements for cement concrete used in manufacturing lightweight concrete masonry units (CMU). These requirements are summarized in Table 1.

As would be expected, the strength requirements for load-bearing blocks are higher than those for nonload-bearing units. However, from the viewpoint of block production there is no real advantage to producing nonload-bearing blocks whereby small quantities of cement may be saved but a different product line is involved. The standard does not specify the cement concrete mix design for blocks, thus allowing a degree of flexibility in the choice of aggregates and cement-to-aggregate ratios.

Table 1. LWA and Cement Concrete Requirements for CMU Applications

Lightweight Aggregate Unit Weight Requirements for CMU (ASTM C 331)				
		Fine lb/ft^3	Coarse lb/ft^3	Combined lb/ft^3
Unit weight, max. values		70	55	65
Industry preference		NA	NA	50
Lightweight Concrete Unit Weight and Strength Requirements for CMU				
			28-Day Compressive Strength	
	ASTM	**Unit Weight lb/ft^3**	**Gross psi**	**Net* psi**
Load-bearing				
- below grade	C 90	<105	1000	2000
- above grade	C 90	<85	700	1400
Nonload-bearing	C 129	105	NA	600

*Net compressive strength values calculated by assuming net cross-sectional area is 50% of gross area.

After two types of expanded slag materials were delivered at the concrete block making facility, mix designs were prepared in the laboratory to test their compressive strength, rate of strength increase over 3-, 7-, and 28-day periods, and the unit weight of the concrete. Test mixes were formulated with the objective of manufacturing two types of blocks:

- Normal-weight blocks with a dry weight of approximately 33.5 lb
- Lightweight blocks with a dry weight of approximately 27 lb.

For both block mixes, conventional lightweight aggregate LWA (H) was replaced by slag lightweight aggregates of two types:

- Fine slag lightweight aggregate produced from 10 x 50M slag feed (SLA F)
- Coarse slag lightweight aggregate produced from 1/4" x 10M slag feed (SLA C).

Table 2 provides size distribution data for the aggregates used by Harvey Cement along with the size distribution of SLA C and SLA F. The size gradation is a critical parameter because it determines the workability of the block mix.

Table 2. Size Distribution of Aggregates Used for Concrete Block Application

Size Fraction	Limestone Screening, wt%	Sand Slag* wt%	SLA F wt%	SLA C wt%	LWA H wt%
+3/8"	0.0	0.0	0.0	3.5	0.0
3/8" x 4M	0.2	9.3	0.5	8.7	1.3
4 x 8M	18.2	26.2	9.2	61.5	26.5
8 x 16M	30.7	20.1	54.8	24.1	25.6
16 x 30M	19.4	14.8	23.0	1.1	17.0
30 x 50M	13.0	11.8	10.8	1.1	11.9
50 x 100M	9.2	8.7	1.7	0.0	7.3
100M x 0	9.3	9.1	0.0	0.0	10.4
Total	100	100	100	100	100
Unit wt, lb/ft^3	83.8	88.2	43.9	44.7	52.9

* Blast-furnace slag fines used in place of concrete sand.

The mix designs used for block production are shown in Table 3. As may be seen, the cement-to-aggregate ratio used was identical to that currently used at the plant. For lightweight blocks, the cement-to-aggregate ratio was 1:6.6, and for regular blocks it was 1:8.7. Water was added on an as-required basis depending on the overall workability of the aggregates and the cement paste in the mix.

Table 3. Results of Batch Mix Tests Conducted for Masonry Blocks Using SLA

	Materials Used by Volume, ml						Compressive Strength, psi		
Test Batch	**LS**	**SS**	**SLA F**	**SLA C**	**Total Aggr.**	**Cement**	**3-day**	**7-day**	**28-day**
Unit wt, lb/ft^3	83.8	88.2	43.9	44.7		94.0			
Regular-weight block mixes (cement-to-aggregate ratio of 1:8.7 by volume)									
21997-1	1650	630	720	-	3000	346	1090	1246	1636
21997-2	1650	630	-	720	3000	346	1285	1324	1519
Lightweight block mixes (cement-to-aggregate ratio of 1:6.6 by volume)									
21997-3	1290	-	1710	-	3000	453	1012	1168	1402
21997-4	1290	-	-	1710	3000	453	934	1012	1168
21997-5	645	-	855	0	1500	264	1051	-	1519

Test specimens (2" x 4" cylinders) were made from the concrete and stored in a curing chamber used to cure commercial blocks. A total of nine blocks were made for each batch, which allowed three blocks per compression test. These tests were conducted after 3, 7, and 28 days of curing. For the last batch, only six specimens were made, which were tested after 3 and 28 days of curing.

The compression test results indicate that at the 1:8.7 and 1:6.6 cement-to-aggregate ratios, the 28-day strength was below the ASTM requirement of 2000 psi for load-bearing blocks. These strength values may be increase by adding a higher proportion of cement to the mix or increasing the slag sand or limestone sand content.

The blocks made using fine expanded slag (SLA F) proved to have higher compressive strength than those made from the coarser expanded slag (SLA C). For example, a regular block mix using SLA F (Test 21997-1) had a 28-day compressive strength of 1639 psi, while one made using SLA C had a strength of 1519 psi (Test 21997-2). A similar trend was apparent in the case of lightweight blocks in which higher quantities of SLA were used. Test using a higher proportion of cement to improve strength are currently being planned.

4.2 Laboratory Evaluation of SLA for Structural Concrete Application

The objective of this test program was to develop mix designs to produce sand and SLA-based cement concretes with a compressive strength of 2500-4000 psi at corresponding unit weights in the 115-105 lb/ft^3 range. This was accomplished by varying the proportion of cement relative to SLA. The tests were completed recently and the results are awaited from the laboratory.

The ASTM unit weight requirements for the structural concrete aggregates are summarized in Table 4. Also provided in this table for purposes of reference are the unit weight and compressive strength requirements for cement concrete mixtures produced from 100% LWA or various mixtures of LWA and sand.

Table 4. Lightweight Aggregate and Structural Concrete Unit Weight and Compressive Strength Requirements (ASTM C 330)

Structural Lightweight Aggregate Unit Weight Requirements			
	Fine	Coarse	Combined
	lb/ft^3	lb/ft^3	lb/ft^3
Unit weight, maximum values	70	55	65

Lightweight Structural Concrete Unit Weight and Strength Requirements	
Concrete Unit Weight	28-Day Compressive Strength
lb/ft^3	lb/in^2
All Lightweight Aggregate	
110	4000
105	3000
100	2500
Sand-Lightweight Aggregate	
115	4000
110	3000
105	2500

Table 5 lists the slag-based aggregates and control aggregates that were tested. The table also provides the size gradation specified in ASTM C 330 in conformity with which the aggregates were prepared.

Table 5. Samples of Materials Used for Structural Aggregate Testing

Sample ID	Aggregates and Production Methods	Gradation to ASTM C 330	Unit Weight lb/ft^3
951132	Pelletized slag/clay (50/50 SLA)	3/4" coarse	40.9
951133	Clay LWA produced in pilot plant from clay used as binder to produce 50/50 SLA pellets	3/4" coarse	48.9
950931	SLA produced from 1/4" x 50M Slag I	3/8" combined	51.2
960234	Commercial LWA product (expanded clay)	5/8" coarse	34.0
960235	Commercial LWA product (expanded clay)	3/4" coarse	38.0
960233	Commercial LWA product (expanded clay)	3/8" combined	53.8
	Concrete sand	Fine size (4M x 0)	102.0

The clay LWA and commercial LWA were used as control materials. The slag and clay-based expanded aggregates produced in the pilot plant were crushed to meet ASTM C 330 size specifications prior to being used. The samples of commercial LWAs were obtained from a commercial lightweight aggregate plant and used without crushing in the control tests since they were prepared to the appropriate ASTM size gradation specification. The size distribution of these materials is given in Table 6. The data indicate that the size distributions of SLA and 50/50 SLA (both prepared as 3/4" coarse aggregates) are generally coarser than commercial aggregates with the same designation although they fall within the allowable range.

Table 6. Size Distribution of LWA Materials and Sand Used in Structural Concrete

	Commercial LWA			50/50 SLA	Clay LWA	SLA	Sand
ASTM C 330 Size	5/8" coarse	3/4" coarse	3/8" combined	3/4" coarse	3/4" coarse	3/8" combined	
Unit weight lb/ft^3	34.0	38.0	53.8	40.9	48.9	51.3	
Size Distribution, wt% passing							
1"	100.0	100.0	100.0	100.0	100.0		
3/4"	100.0	100.0	100.0	100.0	100.0		
1/2"	81.3	95.9	100.0	52.1	33.8		
3/8"	27.5	68.2	100.0	21.1	11.8	100.0	100.0
4 mesh	12.6	6.1	97.0	8.4	4.4	91.9	99.0
8 mesh	8.5	3.1	70.5			59.9	77.0
16 mesh	6.0	2.5	41.3			50.3	55.0
30 mesh	4.0						41.0
50 mesh	3.3	1.7	14.2			20.5	25.0
100 mesh	2.4	--	8.9			15.0	7.0
200 mesh							1.9

The SLA and 50/50 slag/clay SLA, both in the form of 3/4" coarse aggregates, were tested at three levels of cement (complete matrix), whereas the other samples were tested at one level of cement or more if needed. The aggregates used and the cement levels tested are listed in Table 7.

Initial tests were conducted using SLA without sand to evaluate all slag aggregate mixes. However, the resulting concrete proved to be much lighter and hence lower in strength than that required by ASTM C 330. Therefore, most of the subsequent tests were performed using sand-based mixes.

Table 7. Expanded SLA Products Tested and Cement Levels Used

Lightweight Aggregate Products Tested	Concrete Cement sacks/yard^3
Sand-Lightweight Aggregate Tests	
1. 50/50 SLA as 3/4" coarse aggregates	5½, 6½, and 7½
2. SLA (from 1/4" x 50M Slag I) as 3/8" combined aggregates	Min. one level of cement
3. Clay LWA produced in the pilot plant from the clay used as a binder for producing 50/50 SLA	Min. one level of cement
4. Commercial LWA product (expanded clay)	Min. one level of cement
All Lightweight Aggregate Tests	
5. SLA (from 1/4" x 50M slag) as 3/8" combined aggregates	One level of cement
6. Clay LWA produced in the pilot plant from clay used as a binder for producing 50/50 SLA	One level of cement

Testing and Evaluation Procedure
Cement concrete mixes were prepared from the slag aggregates listed above. The aggregate-to-cement ratios used were identified in exploratory tests, with the objective of achieving 28-day strengths of 2500, 3000, and 4000 psi, respectively. Approximately 12-15 test specimens were prepared for testing using the following procedure:

- Adjust the moisture content of the aggregates to saturated surface dry (SSD) conditions by saturating overnight. Document the moisture content.

- Estimate the sand content required for the concrete mix to achieve a suitable gradation without exceeding the unit weight specification.

- Document the dosages of the air-entraining agent used.

- Prepare test specimens using the SLA sample with a preselected aggregate-to-cement ratio and slump. Measure the water added to document the cement-to-water ratio.

- Document the total weight and volume of the ingredients used and calculate the sand-to-LWA ratio and water-to-cement ratio by weight. Measure the unit weight of the fresh concrete. Report the workability of the mix.

- Test the specimens for compression following 1-day (early strength), 3-day, 7-day, and 28-day curing time periods. Save 3 cylinders for further testing.

- Prepare control test specimens using the commercial LWA sample with an identical aggregate-to-cement ratio and slump. Measure the water added to document the cement-to-water ratio. Measure the unit weight of the concrete and its compressive strength for 3-day, 7-day and 28-day curing time periods for purposes of comparison.

- Test specimens were saved in order to conduct the following tests at a later date if desired:
  - Freeze/Thaw, ASTM C 666
  - Drying Shrinkage, ASTM C157
  - Staining, ASTM C 641

Results of Laboratory Tests for SLA Concrete Mixes Made Without Sand
Exploratory laboratory studies were conducted using SLA to make lightweight concrete without sand in order to evaluate its potential as a structural aggregate as per ASTM C 330. These tests were performed using three levels of cement. The results are summarized in Table 8. The following problems were experienced with these tests, with the exception of Test 4:

- The lack of fines made the concrete mix too coarse and hence unworkable.
- The water separated from the mix.
- The product unit weights, in the range of 67-70 lb/ft^3, were much lower than the target values of 100-110 lb/ft^3.
- The 28-day compressive strength values were in the 843-1877 psi range, far lower than the target of 2500 psi.

Therefore, production of structural concrete by formulating lightweight concrete mixes using SLA without sand was rejected for further consideration.

Table 8: Use of SLA for Structural Lightweight Concrete Without Sand

Test No.	Aggregate Type, Application and Unit Weight		Cement Sacks/ yd^3	W/C Ratio	Slump in.	Air %	Product Unit Weight lb/ft^3	Compressive Strength psi	
	Application per ASTM C330	lb/ft^3						7-day*	28-day
1	SLA as 3/8" combined	51.3	5½	0.6	0	3.8	66.9	375	843
1A	SLA as 3/8" combined	51.3	5½	0.65	0.5	4.8	67.4	610	963
2	SLA as 3/8" combined	51.3	6	0.65	0.75	4.8	69.6	740	1877
3	SLA as 3/8" combined	51.3	6½	0.65	1.25	4.8	69.9	1180	1840
4	Commercial LWA (3/8" combined)	53.8	6	0.65	1.5	3.9	70.0	-	2370

*Average of three tests.

Results of Laboratory Tests for Various LWA Concrete Mixes Using Sand

The results of laboratory studies to make lightweight concrete mixes using SLA, LWA, and sand mixes are summarized in Table 9.

SLA as 3/8" combined aggregate. Tests to evaluate SLA as 3/8" combined aggregate (produced from 1/4" x 50M Slag I), using 6 sacks of cement/yd^3 of concrete, resulted in 7- and 28-day strengths for the SLA concrete of 1120 and 1750 psi respectively (Test 2199). The unit weight of the concrete was 107 lb/ft^3. The 28-day compressive strength of the 3/8" combined commercial LWA (control sample) was 2400 psi at a unit weight of 115 lb/ft^3. Neither of these aggregates met the ASTM C 330 requirement of a compressive strength of 2500 psi at 105 lb/ft^3 unit weight.

Since the SLA concrete 28-day strength failed to meet the ASTM strength requirement, additional tests were conducted using 6.5 sacks of cement/yd^3 concrete. At the higher cement level, the 28-day strength was 2070 psi at 107 lb/ft^3 which is still considerably lower than the ASTM requirement. The 28-day strength results of the commercially produced LWA at 3440 psi at 112 lb/ft^3 (control test 2206) were much higher than those of the SLA concrete and met the ASTM requirement at the given unit weight level.

Table 9. Evaluation of SLAs for Sand-Lightweight Concrete Application

Test No.	Aggregate Type, Application and Unit Weight		Sand*/ Aggregate	W/C Ratio	Slump in.	Air %	Unit Weight lb/ft^3	Compressive Strength, psi	
	Type and Application per ASTM C330	lb/ft^3						7-day**	28-day
Tests Using 6.0 sacks of cement/yd^3									
2205-A	Commercial LWA (5/8" and 3/4" coarse)	36.0	48/52	0.65	4.0	3.5	119.6	-	-
2205	Commercial LWA (3/4" coarse)	38.0	36/64	0.43	3.5	2.0	112.8	2380	3400
2201	Commercial LWA (3/8" combined)	53.8	45/55	0.65	3.5	4.0	114.8	1500	2400
2199	SLA as 3/8" combined	51.3	43/57	0.65	4.0	3.0	106.7	1120	1750
2208	Commercial LWA as 5/8" coarse	34.0	41/59	0.46	2.5	2.0	113.8	2420	3390
2207	Commercial LWA as 5/8" coarse	34.0	39/61	0.46	2.0	2.0	108.6	2220	3240
2209-A	Clay LWA as 3/4" coarse	48.9	54/46	0.52	7.0	--	115.4	***	***
2209	Clay LWA as 3/4" coarse	48.9	49/51	0.45	3.0	1.0	114.8	3430	4800
2211	50/50 SLA as 3/4" coarse	40.9	44/56	0.48	2.5	2.0	112.3	2910	4210
Tests Using 6.5 sacks of cement/yd^3									
2200	SLA as 3/8" combined	51.3	43/57	0.65	4.0	3.8	107.0	1350	2070
2206	Commercial LWA as 5/8" coarse	34.0	37/63	0.43	2.0	2.0	111.8	2730	3440
2210-A	Clay LWA as 3/4" coarse aggregate	48.9	48/52	0.42	3.5	1.0	115.2	***	***
2210	Clay LWA as 3/4" coarse aggregate	48.9	46/54	0.42	3.5	1.0	114.3	4040	5100
2212	50/50 SLA as 3/4" coarse aggregate	40.9	45/55	0.44	3.25	2.0	114.7	3480	4360

*Sand unit weight was 102 lb/ft^3, 99% passing 4M, 1.9% passing 200M (dry).
**Average of three tests.
***Test specimen exceeded 115 lb/ft^3.

50/50 SLA as 3/4" coarse aggregate: Tests conducted with 50/50 slag/clay aggregates using 6.0 sacks of cement/yd^3 concrete resulted in 7-day and 28-day concrete strength measurements of 2910 and 4210 psi respectively. The 28-day value exceeds the ASTM requirement of 4000 psi at a unit weight of 115 lb/ft^3. These results were far superior to those of tests done using SLA (3/8" combined) at the same cement level, as well as to control Test 2205 using commercially manufactured aggregates which had a strength value of 3400 psi.

The tests conducted at the higher (6.5 sacks/yd^3 concrete) cement level resulted in compressive strengths of 3480 and 4380 psi for the 7- and 28-day curing periods, respectively (Test 2212), at a unit weight below 115 lb/ft^3. The control test strengths using clay LWA (Test 2210) were 4040 and 5100 psi which are in a comparable range. The 28-day compressive strength of the concrete using commercial LWA at the 5/8" size designation was 3440 psi, which is lower than that resulting from use of the expanded slag/clay-based aggregate. These data indicate that blending slag and clay results in a high-quality product.

4.3 Laboratory Evaluation of Slag III as a Feed Material for LWA Production

A third slag sample (Slag III) was obtained from the Wabash River Repowering Project IGCC plant. This slag was added to the project with the objectives of (i) extending the project findings to another slag, and (ii) producing a batch of SLA suitable for structural applications, with higher strength than those produced from Slags I and II. In order to achieve higher strength, the new SLA product will be generated at a unit weight of about 55 lb/ft^3, (i.e., higher than produced previously) which is expected to result in both a stronger aggregate and stronger concrete.

Laboratory-scale expansion tests using Slag III generated a product with a low unit weight of 22.1 lb/ft^3 from discrete particles at a lab furnace temperature of 1600°F. These results indicate that a product with a unit weight in the 30-55 lb/ft^3 range could be produced at temperatures of <1500°F. We have requested a large sample of this slag for testing at the pilot scale. The sample will be shipped as soon as the gasifier can be operated under normal steady-state conditions.

5.0 PLAN FOR THE NEXT QUARTER

The following activities are planned for the next quarter:

- Complete laboratory evaluation of expanded slag products for horticultural applications.
- Complete laboratory testing and select a mix design for the commercial-scale block-making production run.
- Complete laboratory evaluation of the slag lightweight aggregates for structural applications.